

DESIGNING INFORMATIVE SOUND TO ENHANCE A SIMPLE DECISION TASK

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ABSTRACT

In this paper we examined the role of informative sound in a simple decision-making game task. A within-subject experiment with 48 participants measured the response time, success rate and number of timeouts of the players in a number of eight-second decision tasks. As time proceeds, the task becomes easier at the risk of players timing out and reducing the overall opportunities they will have to attempt the task. We designed a simple informative sound display that uses a tone that increases in amplitude over the duration of the task. We test player performance in three conditions, no sound (visual-only), constant (non-informative) sound and increasing (informative) sound. We found that the increasing sound display significantly reduced timeouts when compared with the visual only and constant sound versions of the task. This reduction in timeouts did not impair the players' performance in terms of their success rate nor response time.

1. INTRODUCTION

The aim of this study is to understand the informative use of sound in a simple decision-making task. We are motivated to better understand interaction in computer games where a player's fast decision-making is often critical to performance. The amount of time taken to make such decisions can be affected by the amount of information the player possesses in their current situation. Assuming that extra information allows players to perform better at such game tasks, this paper investigates the way sound can be used to provide multi-modal support for decision-making.

This 'informative' use of sound is designed to provide additional feedback related to the players' own actions, as well as key events and states of the game world. That is, the player can gather information about the game environment by relying upon auditory as well as visual cues. This might be advantageous in situations where visual cues are unhelpful because the eyes are already engaged in processing other signals. Alternatively, auditory displays may provide a more optimal modality for information when temporal cues are required.

In terms of computer games, the role of sound in has certainly evolved since the classic laser sound effects and monotone background music used in nostalgic games such as Space Invaders [1]. Indeed, sound has become an integral part of the experience provided by modern computer games.

Sounds for computer games have traditionally been designed much like sound for motion pictures, as an adjunct to the visual experience. In films, music is used to establish the mood of the scene as well as to evoke tension and emotional responses from the audience [2]. Sound effects in film tend to enhance the realism of the scene with the intention of creating greater levels of immersion for the viewer.

Rightly or wrongly, computer game designers tend to focus on visual perceptual cues when designing the game levels [3]. Like the sound in films, the auditory effects are mainly added to enhance the visual experience [4]. In accordance with this approach, much research on sound display within video games has focused on how sound enhances players' experience and immersion [4-8].

Of course, one consequence of using sound solely for visual enhancement is that the design of more informative sound can be overlooked. For some user groups, such as the visually impaired, this can even exclude them from being able to play the game [9]. A more subtle consequence is that the full potential of using sound to convey useful messages is not always exploited in games. This is despite many studies within the field of auditory display [4,10-17] that provide evidence for the value of auditory feedback. It is clear that in many situations, well-designed sounds can provide important, additional feedback for computer users [7, 17-22].

While sound is usually designed as an adjunct to visual experiences in computer games, some games do exploit sound in more informative ways. These include Papa Sangre [29], a horror themed audio game for the iOS mobile platform that uses sound effects to guide the player in the dark environment. Likewise, the recent Thief series [30] integrates sound into the gameplay and uses it as the primary feedback for navigation. Informative sound is also present in some online multiplayer games such as World of Warcraft [31] where the sounds provide a more general informative function that supports player orientation and the identification of key situations and states [21].

Many approaches exist for supporting the design of sound displays. These include a case-based, metaphorical approach for aligning the informative function of sounds to listening encounters from the real world [23] and a structured multi-sensory taxonomy with guidelines that considers all

modalities for the display [24]. Another approach relies on the use of Auditory Design Patterns [12,25,26]. This approach has been considered for both general auditory display [12] and specifically for use in video games [25,26].

Probably, the two most well-known techniques described for displaying information through sound are Auditory Icons [10] and Earcons [13]. The technique known as Auditory Icons was first investigated as a means of extending the use of visual interface icons to the auditory dimension [10]. Based on ‘everyday listening’ skills, this approach maps information to recognisable sounds from the real world. By using a recognisable sound, the user can intuitively understand the current action or event suggested by the sound. For example, hitting a tin with a stick is an event that generates a sound. The sound itself conveys information about the material and size of the tin and if it is full or hollow. The sound also conveys information about the materials involved, the frequency of hitting and the force of the hitting. This is information we naturally learn to interpret from our everyday experiences.

There are many instances of natural-like sounds used to augment computer interfaces. For example, the SonicFinder integrated running and pouring sounds in the Macintosh interface to represent file manipulations on the desktop [11]. In the SharedARK application, a virtual physics laboratory for distance education included sounds such as hums that mapped to the state of the physics being simulated [27]. The ARKola bottling system, mapped sounds to equipment in a soft-drink factory, introducing audio cues for monitoring the bottling process [27].

The second common method of designing informational sound is the use of Earcons [13]. Earcons are abstract, synthetic tones that are structured to create auditory messages. This approach relies on ‘musical listening’ skills as it conveys information using musical properties of sound such as rhythm, timbre, and the pitch of notes. This can be contrasted with Auditory Icons that use everyday listening skills rather than acquired musical expertise.

Studies on the effectiveness of Earcons for conveying information have been conducted since the 1990s. Brewster et al [14] experimentally tested the effectiveness of Earcons in providing navigational cues within a structured menu hierarchy. The results found that 81.5% of participants successfully identified their position in the hierarchy, indicating that Earcons can be a powerful method of conveying structured information. Polotti et al [28] evaluated the use of rhetorical Earcons to map common operating-system functions in a graphical interface and found that subjects benefited from additional sound feedback when performing key tasks such as cutting and pasting.

Compared with Auditory Icons, Earcons have the advantage of being able to convey complex information about events to the user without any natural associations with a sound source. On the downside, Earcons require prior understanding of the mapping between the sound and the event before the information can be recognised. By contrast, Auditory Icons are considered to be more intuitive as they leverage the existing listening skills of users.

Currently, only a limited amount of work relating Auditory Icons and Earcons to computer games has been reported. Jørgensen [21] noted that both these approaches can play a role in terms of enhancing control functions for the player by extending the player’s current range of vision. There are also some taxonomies of sound usage described in the context of games [32-34]. The use of Earcons and Auditory Icons and their relationship to player performance

in Defence of the Ancients 2 (Dota 2) [35], a popular multiplayer online battle arena game, have also been reported [36].

However, the informative use of sound has a much longer history of study in domains outside of games [18]. With applications have been reported in diverse domains ranging from file management [11] to hospital operating rooms and vehicle safety systems [39-41]. Leveraging these informative approaches to using sound can potentially allow more critical information to be integrated into game interfaces. This intent would be to improve traditional usability criteria such as effectiveness, utility and efficiency [10,11,26,37,38] without impacting on the immersive experience that games strive for.

Interestingly, the effects of additional sound information, on top of existing visual information, are not always beneficial. The auditory Stroop effect [42] demonstrates how performance can deteriorate when the visual and auditory information are in conflict. Moreover, given the ultimately limited capacity of the brain to process information [43,44], additional sources of information, though relevant to the task at hand, may overload the system and impair performance. Thus, the potential benefit from adding auditory information to visual displays is not trivial and requires careful empirical scrutiny. This is precisely the aim of the current study to evaluate user performance in a multimodal decision-making task.

2. A SIMPLE DECISION MAKING TASK

We developed a simple, custom-built decision-making game, called Buckets. It was designed to allow for the controlled collection of performance data, something that can be difficult in commercial games due to the complexity of interactions. Our Buckets game consists of a repeated task that was initially designed as a visual-only perceptual challenge for measuring how players employ strategy, balancing the risks and rewards associated with game mechanics [45].

Balancing risk and reward is an important consideration in the design of computer games and has even been likened to the thrill of gambling [46]. Of course, if players gamble on a strategy, they assume some odds, some amount of risk. In gameplay it is reasonable to expect that greater risks will be compensated by greater rewards. Adams not only states that each “risk must always be accompanied by a reward” [46] but also describes this as a fundamental rule for designing computer games.

In the Buckets game, players must solve a perceptual challenge, deciding which of four rectangles (buckets) is filling up with dark blue dots (rain) the fastest. The game is comprised of repeated trials. On each trial a new display of four buckets appears and the player has one attempt to determine by a key press which of the four items is the target. A new trial with a fresh display appears after a response, irrespective of whether it was correct or not. The player’s overall goal in the game is to identify as many target buckets as possible within a fixed time period. The longer a player waits on each individual attempt (trial), the more likely it is that the attempt will result in a positive outcome.

This is because as each attempt progresses, more pixels accumulate in the target bucket, making it easier to discern the one correct bucket from the three incorrect ones. A typical strategy might be to attempt faster responses as this rewards the player with more time for additional attempts. An alternative strategy is to reduce the risk of each attempt

by waiting longer to improve chances of correctly identifying the target bucket.

At the start of each trial four buckets are displayed (see Fig. 1). Each bucket consists of 5,000 pixels (50 wide x 100 high). At the start of the game each of the four buckets are 50% filled with 2,500 dark blue pixels and 2,500 white pixels. The actual position of the 50% of dark pixels is chosen randomly at every update of the display. For each trial one of the four buckets is randomly chosen to serve as the target. Each decision may last only up to 8 seconds within the trial, where this target bucket will gradually increase its number of blue pixels until it is 52.5% filled. This number was chosen by trialing the game and using the empirical data to set a difficulty level that gave players a 40-60% chance of success. If no response was given within 8 sec, a new trial begins and no score will be added to the player.

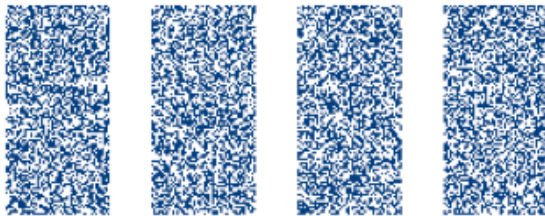


Figure 1: Buckets Perceptual Challenge

The frame rate of the game is configured to ensure that the display is updated at 10 frames per second. This means that about 14 pixels of extra filling are added to the target bucket at each frame. The actual frame rate of the game is monitored to ensure it meets this required number of frames per second.

Note that a player has only 8 seconds to respond, if they wait too long they timeout, losing the opportunity to make a selection. After collecting initial empirical data for the game we found an unexpected consequence of the design was that many players would experience these timeouts. This would negate the benefit that was meant to accrue by waiting longer to make a decision. To address this timeout problem, a simple sound alarm was designed. A beep was used to warn the player that they had 2 seconds left to respond. Unfortunately when trialing this solution the alarm proved distracting to some players, diverting them from their primary task and forcing them to make an immediate decision rather than allowing them to maintain focus on their primary perceptual challenge.

While such auditory alarms are commonly used as warnings, they are intended to divert user attention away from their current task. However, peripheral sounds have also been found useful for background monitoring of system states. We therefore implemented a simple background sound that increased in amplitude over the 8 seconds of the task decision. This sound can be described as an auditory icon as the increasing sound acts much an alarm of an approaching car. The sound becomes louder (and more dangerous) towards a critical moment in time. There are some contraindications for using amplitude in this way [14], so we also considered increasing the frequency of the sound, however this required us to resolve the complex relationship between pitch and amplitude [17], something that was difficult to resolve in the software platform we used. Initial trials with this increasing amplitude sound, anecdotally at least, created a suitable alarming signal and thus we adopted this approach for further empirical testing.

3. METHOD

The sound-augmented Buckets game was tested by comparing player performance in three conditions: *no sound*, *constant sound* and *increasing sound*. The first, 'no sound' condition used the original, visual only version of the Buckets game. The second condition used a 'constant sound' generated using a sine wave of fixed frequency (440 Hz). Musically, this corresponds to A in the fourth octave. This sound played at constant amplitude throughout the 8 seconds of each attempt. This condition was intended as a further control for comparing performance with the 'increasing sound' condition. The increasing sound was generated as a sine wave where the frequency of the signal was held constant at 261 Hz. Musically this corresponds to middle C. The amplitude of the signal gradually increased, in a linear fashion, over the 8 seconds of each trial. The increasing sound was pre-recorded as an 8 second wav file that was triggered for play at the start of each trial.

We tested the game using a repeated measure design with 48 psychology and computing students, and academics, from the University of Newcastle. Psychology students were awarded course credit for their participation. The study was approved by the University of Newcastle's Research Ethics Committee. Participants were predominantly male (71%) and ranged in age between 18-54 years, with an average age of 21. All participants had normal, or corrected normal, vision and hearing.

The experiment was conducted within a computer laboratory. On arrival, each participant was assigned a workstation that displayed the Buckets game. All data was collected using an Apple Mac Pro running OS X 10.8 Mountain Lion. The game was played online using the Mozilla Firefox (Version 22) web browser and the Flash Player (version 11.4). Each participant wore a full sized headphone (AKG K44) during the whole experiment, even in the no sound condition. During the experiment the volume level on the operating system was set at the lowest possible volume (1 out of 16 bars).

Each participant played in each of the three conditions: no sound, constant sound and increasing sound. The order of the three conditions was counter-balanced across participants to control for effects learning and fatigue effects. Participants were randomly allocated to an order of conditions. Regardless, each participant received one minute of practice time in each condition before playing that condition competitively for 15 minutes. These 15 minutes were further divided into three blocks of, five minutes each.

As each condition began, the participant was presented with the game rules. These rules emphasized the importance of both accuracy and speed in the task. At the end of each individual trial the player received feedback for 500 milliseconds regarding their choice of buckets. A green tick was displayed below the target square if the decision was correct. This was accompanied by a cash-register sound. If the player choose incorrectly a red cross was displayed below the target and a sigh-of-disappointment sound played. Where the player timed out an alarm clock was displayed, and a typical alarm clock sound was played.

At the completion of each of the five minute blocks, participants received summary information about their performance, namely their number of correct and incorrect responses. At the end of each sound condition the subject was allowed a two minute break before commencing the next assigned condition. Overall subjects completed the experiment in about 60 minutes.

The player's response time for each attempt, and their timeout status for that attempt, were recorded for later analysis. Data regarding the correct target bucket (1-4) and the player's actual selected bucket (1-4) for each attempt were also saved.

4. RESULTS

Overall, the players completed 20,173 trials, with 8,347 of these trials resulting in correct responses (41.38%). There were 11,369 (56.36%) incorrect responses and a further 457 (2.27%) timeouts recorded. The task was designed to allow for a success rate between 40-60% (to allow a sufficient number of both correct and incorrect trials for analysis, see [45].) The results show this preliminary goal was achieved, so we move on to two further types of analysis. We first performed (section 4.1) further analysis on the pooled data to gain an overall appreciation of the data. This pooling process results in unequal number of trials for each condition, so within-group analysis cannot be used. A more traditional within-group analysis of the data is performed in section 4.2

4.1 Pooled Trial Results

The average response time of participants was 3.97 seconds (SD=1.98). A paired-samples t-test was conducted to compare the response time in winning trials and losing trials (excluding timeouts). There was a significant difference in the response time for winning responses (M=4.40, SD=1.81) and losing response (M=3.50, SD=1.88); $t(19718)=1.96$, $p < 0.05$. Again this was expected, as the task was designed so that responding more slowly would improve the player's chance of success.

Next we considered all trials in relation to the three experimental conditions. Overall, the 48 players completed 6,818 trials in the no sound condition, 6,661 trials in the constant sound condition and 6,694 trials in the increasing sound condition. In the no sound condition there were 2,794 (40.98%) correct responses, 3,830 (56.17%) incorrect responses and 194 (2.85%) timeouts. In the constant sound condition there were 2,717 (40.79%) correct responses, 3,773 (56.64%) incorrect responses and 171 (2.57%) timeouts. In the Increasing sound conditions there were 2,836 (42.37%) correct responses, 3,766 (56.26%) incorrect responses and 92 (1.37%) timeouts.

We designed the increasing sound as a temporal cue to reduce timeouts; it seemed to be effective with 2.85% of timeouts in the no sound condition, 2.57% in the constant sound and 1.37% in the increasing sound condition. A chi-square test of goodness-of-fit was performed to determine whether timeouts occurred equally across all sound conditions. Timeouts were not equally distributed in the experiments, $\chi^2(2, N=457) = 49.09$, $p < 0.05$. Unlike the timeouts, there were no significant differences in the number of correct responses $\chi^2(2, N=8,347) = 2.37$, $p=0.30$ or incorrect responses $\chi^2(2, N=11,369) = 0.15$, $p=0.93$ across the three conditions. This suggests that apart from the reduction in timeouts, there were no changes in players' hit rate (accuracy) when sound was included in the display.

However, using a one-way ANOVA we found a significant effect of sound on mean response time for all trials at the $p < 0.05$ level for the three conditions [$F(2, 19713) = 15.26$, $p = 0.00$]. Post hoc comparisons using the Tukey HSD test indicated that the mean response time for the no sound condition (M = 3.77, SD = 1.93) was significantly faster than both the constant sound condition (M = 3.93, SD

= 1.89) and the increasing sound condition (M = 3.94, SD = 1.88). The constant sound condition did not significantly differ from the increasing sound condition.

We then considered mean response time from winning trials separately from the response time for losing trials. Again there was a significant effect of sound on mean response time for both the winning trial data at the $p < 0.05$ level for the three conditions [$F(2, 8344) = 12.31$, $p = 0.00$] and the losing trial data [$F(2, 11366) = 5.03$, $p = 0.01$].

In terms of wins, post hoc comparisons indicated that the mean response time for the no sound condition (M=4.26, SD=1.85) was significantly faster than the constant sound condition (M=4.48, SD=1.81) and the increasing sound condition (M = 4.47, SD = 1.76). The constant sound condition did not significantly differ from the increasing sound condition. This overall pattern was consistent with the loss data where post hoc comparisons indicated that the mean time for the no sound condition (M=3.42, SD=1.91) was significantly faster than the constant sound condition (M=3.53, SD=1.85) and the increasing sound condition (M=3.54, SD=1.87). Again, the constant sound condition did not significantly differ from the increasing sound condition.

These results were pleasing from our design goals, as they provided further indication that (i) players avoided timeouts in the increasing sound condition, and at the same time (ii) were able to wait longer to respond than in the original no sound condition. What was most surprising about these results is that players also seemed to wait longer to respond in the constant sound condition, although this produced no significant reduction in timeouts. This constant sound condition was included as a control condition and was not expected to produce any variation in the way players performed the task.

4.2 Player by Player Results

After examining effects from pooled data, we also considered the player-by-player results. That is, the mean result for each player in each condition was calculated before analyzing these results in a one-way repeated-measures design. On average players completed 420.27 (SD=81.43) trials, 142.04 (SD=33.40) in the no sound condition, 138.77 (SD=27.69) in the constant sound condition and 139.46 (SD=31.54) in the increasing sound condition. The minimum number of trials completed by a player was 318. The maximum number of trials by a single player was 697.

Given the variation in number of trials that players completed we were concerned that our overall results could be biased, or over weighted, by individual performance. We therefore repeated our pooled-data analysis by using the averaged results for the 48 players. This entailed averaging all trials for each of the 48 individual players to find their averages and then finding the average of these 48 results.

First we considered the average number of winning trials for each player in the three conditions, no sound (M=58.21, SD=17.82), constant sound (M=56.60, SD=18.86) and increasing sound (M=59.08, SD=17.01). A repeated measures (within subjects) one-way ANOVA showed no significant difference between the number of wins in the three sound conditions, $F(2,47) = 0.70$, $p = .497$.

Next we considered the number of losses per player in the three conditions, no sound (M=79.79, SD=39.37), constant sound (M=78.60, SD=7.62) and increasing sound (M=78.46, SD=39.18). Again a repeated measures (within subjects) one-way ANOVA showed no significant difference, $F(2,47) = 0.06$, $p = .946$.

We then analyzed the number of timeouts in the three conditions, no sound ($M=4.33$, $SD=4.87$), constant sound ($M=3.54$, $SD=3.79$) and increasing sound ($M=1.65$, $SD=2.55$). In this case a significant difference was found between the number of timeouts in the three sound conditions, $F(2,47) = 13.36$, $p < .05$ (0.000). Post hoc comparisons with Bonferroni correction confirmed that increasing sound resulted in a significantly lower number of timeouts compared to the no sound condition ($p = .01$). There were no significant differences between either the no sound and constant sound or the constant sound and increasing sound conditions.

We then considered the average response time for all trials, per player ($n=48$), in the three conditions, no sound ($M=4.08$, $SD=1.21$), constant sound ($M=4.18$, $SD=1.14$) and increasing sound ($M=4.22$, $SD=1.21$). A repeated measures (within subjects) one-way ANOVA showed no significant difference between the response time in the three sound conditions, $F(2,47) = 0.51$, $p > .599$.

Next, we compared response times for all winning trials per player ($n=48$) in the three conditions, no sound ($M=4.22$, $SD=1.23$), constant sound ($M=4.40$, $SD=1.11$) and increasing sound ($M=4.40$, $SD=1.20$). No significant difference was found for the players average winning response time, $F(2,47) = 0.98$, $p = .379$.

Finally we considered just the response time for losing trials per player in the three conditions, no sound ($M=3.88$, $SD=1.16$), constant sound ($M=3.94$, $SD=1.08$) and increasing sound ($M=4.04$, $SD=1.19$). Again no significant difference was found for the players average losing response time, $F(2,47) = 0.72$, $p = .492$.

5. DISCUSSION

The key design goals of our multimodal display were validated in the experiment. First the decision-making task had a general success rate of about 41%, within the desired range of 40-60% (necessary to allow a sufficient number of both correct and incorrect trials [45]). However, there was considerable variation between players with four of the 48 players averaging below a 25% success rate and another four achieving higher than 70% of correct responses when all their trials were considered. Fig. 2 shows the distribution of win-percentage across players (the line marks the mean correct rate of 41%).

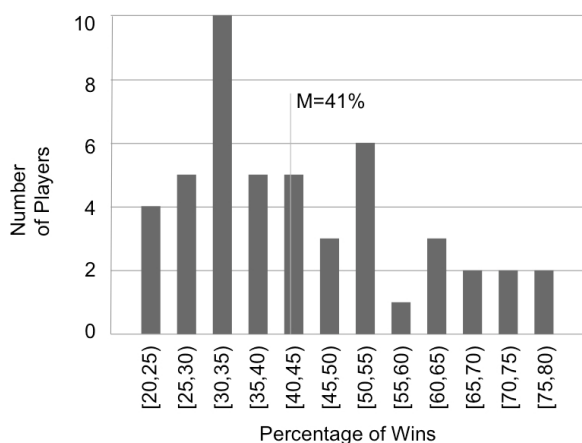


Figure 2: Percentage of wins for players

Second, the application of increasing sound cue to prevent timeouts was also successful. When we analysed all trials together, and then player-by-player, we found a significant reduction in timeouts in the increasing sound conditions compared to the no sound condition. This reduction in timeouts did not seem to come at the expense of players responding more quickly in the task. Indeed when we examined all trials together we found a significant increase in reaction time, so players actually slowed their response time in the increasing sound condition compared to the no sound condition. Overall, they also recorded more wins and fewer losses in the increasing sound condition than the no sound condition. This was consistent with the game design, as we expect the task to become easier as players wait longer.

These results are mitigated by the fact that when we compared the data by averaging player by player outcomes the difference in timeouts was still significant, however, the increase in response time and wins in the increasing sound condition was no longer evident. This suggests there was some bias introduced into the overall results by the performance of individuals in the experiment. Regardless, we can be confident that the player's performance in the multimodal task did not reduce to offset the reduction in timeouts.

The most surprising result was that that when we compared the overall trials we also found a significant difference between the response time and number of wins in the constant sound condition, compared to the no sound condition. Again this is mitigated by the fact that this significance was not evident when we compared the average results over the 48 players. Regardless this is a surprising result and worth further discussion.

The increasing sound signal was specifically designed to allow players to wait longer before deciding. The constant sound was introduced as a control, yet somewhat surprisingly players seemed to wait longer before responding in this condition as well. This could imply they also receive some timing information from this constant sound signal. One explanation for these results is that players have an internal mechanism for measuring time that is activated by a constant sound signal. Indeed such a model has been proposed that describes an internal pacemaker sending a regular series of pulses to some kind of counter mechanism [47].

In this model the internal clock mechanism can also be calibrated by external events. In the buckets game this calibration might occur using the visual updates or the game time outs. The model has also been used to consider how such a clock could impact of cognitive function such as the decision-making task [48]. Because of the need to track time in the constant condition this model predicts that we would see slightly longer response times, yet lower success rates. While this is the case in this experiment, these differences were not found to be significantly different in the constant sound condition compared to the increasing sound condition. Regardless, this interesting result is probably worth further study.

In terms of decision-making tasks in game designs, we have demonstrated the usefulness of gathering empirical data to test player performance on game-like tasks. We have also demonstrated how simple informative sound displays can provide useful information in a perceptual visual challenge.

6. CONCLUSION

Fast decision-making is often a critical task that underpins performance in computer games (and real life). Players in

competitive games are often faced with numerous, rapid decisions in which the final outcome is decided based on the player's current awareness of the situation. This requirement is also true in many business decisions.

In this experiment we compared the performance of players in a simple visual decision-making task and a multimodal version of the same eight-second task. Players must choose between one of four possible outcomes within the eight seconds before timing out. The longer players wait the easier the challenge becomes.

We augmented the visual only task by adding auditory feedback in the form of a sound slowly increasing in amplitude over the eight-second period. When compared with the visual only task, we found that there is a significant reduction in the number of timeouts experienced by players in the increasing sound display. This reduction does not seem to come at the expense of performance, as players seem to wait longer and make more correct responses in the increasing sound condition.

An interesting result that needs further validation is that players also seem to wait longer when a non-informative constant sound was added to the display. This result was difficult to validate as considerable player-to-player variation occurs in the task with average success rates ranging from 21% to 78%. Some players (n=15) performed at least 10% better in the increasing sound display while others (n=14) performed 10% worse with this display. For some (n=19) performance seems relatively unchanged between display modes.

Such variation in performance has previously been reported with multimodal displays [15, 38] and categorised as conflicting, complementary and redundant [49,50]. Where individuals perform worse with multimodal information, the display can be categorised as conflicting; where they perform better it can be described as complementary; and where there is no change in performance the display can be described as redundant. This variability in performance is also worth further study to see if it is consistent among individuals across other multimodal tasks, indicating a particular individual preference or also if it might be mitigated by training.

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